Monsoon Disturbances over Southeast and East Asia and the Adjacent Seas

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LONG TERM GOALS

To study weather disturbances over the East Asian – Western Pacific monsoon region and vicinity using Navy and NCEP data and forecast models. The primary goal is to advance the understanding of the weather-producing systems in the region, in order to improve forecast capabilities.

OBJECTIVES

The objectives are: (1) to study the structure and the dynamic and thermodynamic properties of high-impact weather systems in the vicinity of the Southeast and East Asian monsoon region that stretches from Indian Ocean to the tropical Pacific, including the South China Sea and Yellow Sea, which are of particular interest to naval operations; and (2) to study the ability and sensitivity of Navy operational numerical models in analyzing and predicting these disturbances.

APPROACH

Observational studies/Data analysis: Use archived data from global NWP outputs and satellite data to determine the structure of meso- and synoptic scale disturbances in various local regions for the different seasons. Use composite and principal component approaches to perform statistical analysis of the data.

Modeling: Use dynamic and numerical models to study the interaction of western tropical Pacific monsoon circulation and synoptic tropical disturbances.

WORK COMPLETED

In this year we are continuing the study of Asian winter monsoon surges over Southeast Asia for February-March 2005 which was the most unusually active late season on record. We are analyzing the long-term (past 50 years) data to compare with this season in order to find the special factors responsible. Preliminary results suggest that teleconnections from Atlantic blocking and west Asia are likely the cause. This work is ongoing.

We are also continuing the study of the statistical properties of concentric eyewall formation in western North Pacific tropical cyclones. We have completed a study using data generated by subjectively examining microwave imagery data available from NRL Marine Meteorology Division and best-track data from JTWC for 1997-2005, the preliminary results were reported last year. More

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14. ABSTRACT

To study weather disturbances over the East Asian ? Western Pacific monsoon region and vicinity using Navy and NCEP data and forecast models. The primary goal is to advance the understanding of the weather-producing systems in the region, in order to improve forecast capabilities.

15. SUBJECT TERMS

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importantly, the problems encountered in the subjective determination of the eyewalls from the satellite imageries in this study motivated us to start an effort to objectively determine eyewall structure from the satellite microwave data. Such an approach would remove much uncertainty in the observational studies of tropical cyclone structure and will also provide a consistent and efficient methodology for future studies. This year we have developed the methodology and began to apply it to the 10-year data set for 1997-2006.

RESULTS

Here we focus on the effort to develop a methodology to identify and quantify concentric eyewall structures from satellite microwave data. We started by using the SSMI 85GHz horizontal polarized orbital images obtained from NRL web site (http://www.nrlmry.navy.mil/) as a test data set to determine the distributions of total blackbody temperature (Tbb) near eyewalls and the core sizes over the western North Pacific from 1997 to 2006. The NRL web site documented all orbital satellite images that passed over the typhoons. These images in jpeg files have pixel size of about 2 km. A total of 4417 images were downloaded and checked carefully and among them 1097 images were found to show a clear eye. Subsequently the color jpeg files were converted back to Tbb temperature based on the color table provided in each image. Owing to the orbital satellites, most of the images contain a data missing area. Some of the missing regions were filled with data from nearest pass of geo-stationary satellite according to certain specified criteria. These supplementary filling data are in gray scale which is very easy to remove from the jpeg color picture when needed. Using the eye center location that is manually determined from the images, the typhoon Tbb data can be mapped onto a polar coordinate framework center at the eye. Currently the resolution is chosen to be one pixel (~2 km) in radial direction and one degree azimuthally. In order to minimize the errors from the eye location determination procedure and the possibility of non-circular typhoon eyewalls, five pixels in the radial direction are averaged and referred as one bin. The size of one bin is ~10 km. Then the bins at the same range are averaged and referred as ring-averaged Tbb. Normally each ring has 360 bins. In last year’s report we summarized the result of concentric eyewall structures from a subjective determination in which deep convection that covers 2/3 of a circle are considered a concentric eyewall. In order to compare with this study, we need to find the 240th bin from the lowest Tbb which will is referred to as the 2/3 lowest bin.

Figure 1 is an example of the ring averaged Tbb (black) and 2/3 lowest bin Tbb (red) of Typhoon SAOMAI in 2000. The orbital satellites happened to pass over the typhoon and produced several snap shots that caught the changes of the eyewall. Figure 1a shows a significant low Tbb near 30km from the center of the eye. About 12 hours later a second low Tbb became evident near 100km (Fig. 1b) and then became significant at Fig. 1c and d. Subsequently the inner low Tbb became invisible and left one low Tbb near 70km from the eye. About one day later, Typhoon SAOMAI weakened. This example demonstrated that the jpeg images can be converted back to a digital data set which will allow a quick-look of the typhoon eye wall structures. A single low Tbb-peak indicates a single eye wall and a double low Tbb-peak indicates the existence of double eye walls and a moat in between. If the trend of low peak drops/rises very dramatically, it means the core is very distinct from the surrounding. If the tail after the low Tbb-peak rises gradually, it represents a broad area of convection. Generally there is no convection if Tbb higher than 260K.

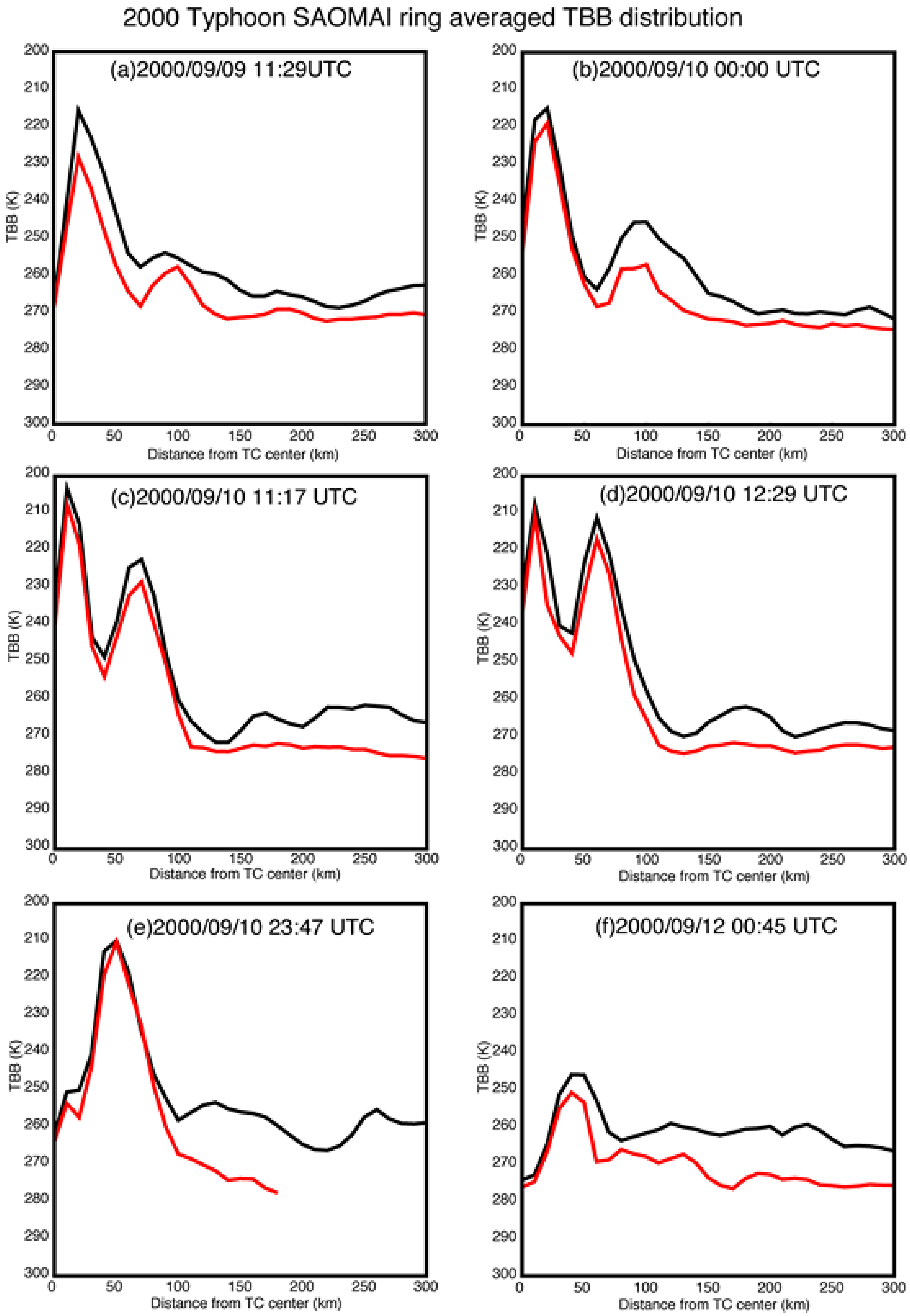

Fig. 1: Tbb as function of raidus of Typhoon SAOMAI (2000).

Fig. 1c and d show double low Tbb-peaks that are the signature of typhoon with double eye walls. Our previous study showed that for most typhoons with double eye walls, the shape of core convections are nearly circular. Using this as an assumption, the Tbb analysis will have two distinct low-Tbb peaks. We therefore develop an automatic double eye walls recognition procedure as below. We started by carefully examining the 1097 typhoon images and associated Tbb profiles. Indeed among most double eye wall cases two main low-Tbb peaks are evident. However, in many cases there are one or more local minimum Tbbs. This caused some difficulties to determine where the eye walls were located. So we designed two criteria to determine the cores locations. First, the core Tbb should be lower than 240K. This is verified by checking all the existing cases. Second, a-five point running mean was computed for use as a buddy check for the minimum Tbb. If the Tbb is the lowest among these five points and its value is 3 degrees lower than the running mean, then it is assigned as the core location. The moat is located at the highest Tbb between the inner and outer convection rings. A total of 105 images were determined to have the double eye walls signature. The mean values of Tbbs and their corresponding locations for the inner core, the moat and the outer core are 237.8K at 32.9km, 263.4K at 64.2km, and 239.3K at 104.6km, respectively. There is a great range of variations on the size of cores (radius of the eyes as defined by the location of the eyewall clouds), the moat, and their Tbb values.

Figures 2a and 2b are the same plots of the distribution of all the Tbb profiles but with different coloring schemes. The colors in Fig. 2a are based on the size of the inner eye, in which the black color indicates typhoons with averaged inner eye radius (within one standard deviation), green color indicates inner eye radius one standard deviation or more shorter than average, and red color indicates inner eye radius one standard deviation or more longer than average. Fig. 2b contains the same profiles and the same color convention except it is based on the size of the moat rather than inner core. The two figures clearly display the large variation and a lack of obvious relationship between the sizes of the inner core and the moat. Some concentric typhoons have very tight eye walls and some have larger eye walls. The areas of eyewall convection in some typhoons are narrow and in some others are rather broad. A casual comparison of Figs 2a and 2b shows that the distribution of core size is more normal while that of the moat size is more skewed towards larger values.

Figure 3 is a first attempt to composite the 105 double eyewall Tbb profiles. Here each profile is “normalized” by linearly interpolated to a 21-point array, with the inner core radius, moat, and outer core radius anchored at point 6, 11, and 16, respectively. The thin black lines are plots for each case. The Tbb values at the two eyewalls and the moat, as well as the differences between the Tbb values at the two eyewalls and the moat, all vary greatly. The mean values and one standard deviation above and below are plotted in yellow, red, and green, respectively. It is interesting to note that the standard deviation of the mean values at the two eyewalls and that of the moat are similar, and the mean Tbb differences between the moat and each of the two eyewalls are about 25 degree C.

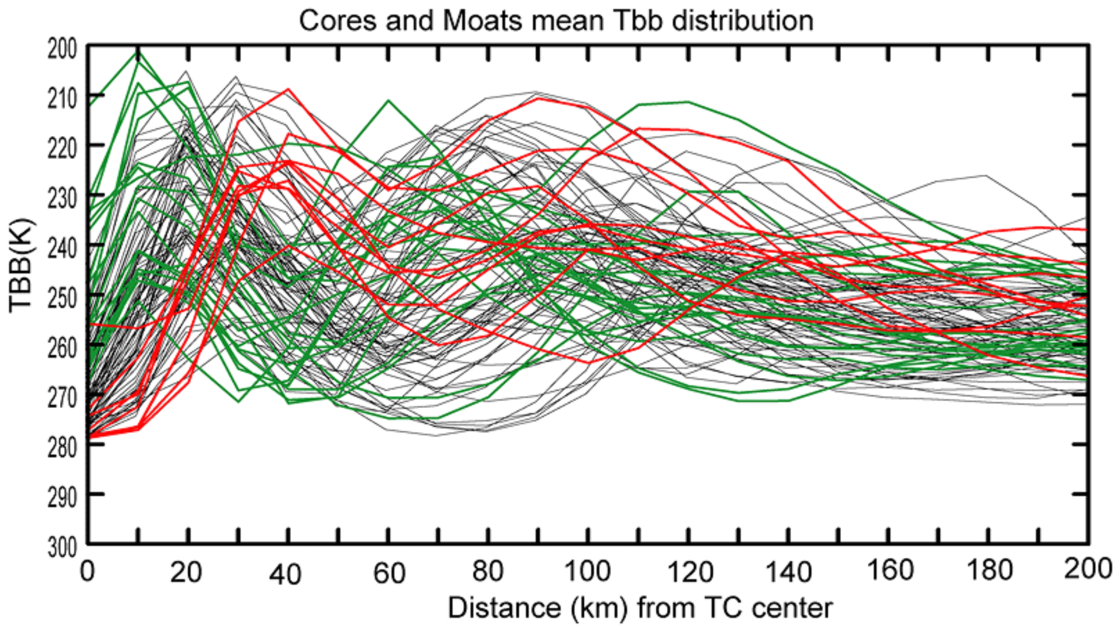

Fig. 2a: Distribution of Tbb profiles for individual typhoons. Color scheme based on the size of the inner core (black: within one standard deviation, green: shorter than one standard deviation, red: longer than one standard deviation).

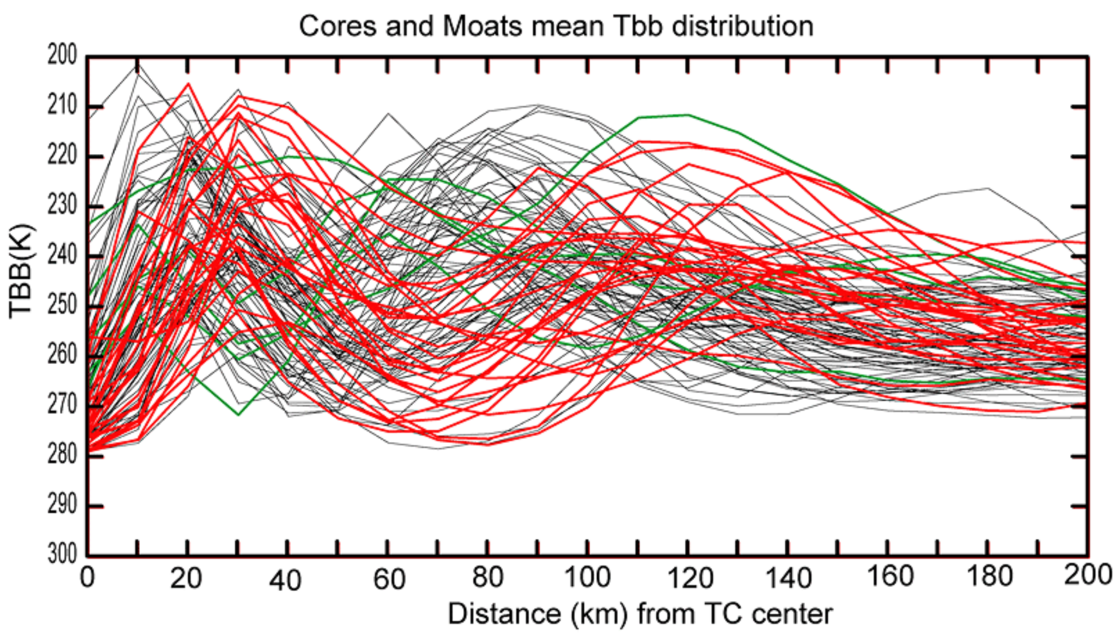

Fig. 2b: Distribution of Tbb profiles for individual typhoons. Color scheme based on the size of the moat (black: within one standard deviation, green: shorter than one standard deviation, red: longer than one standard deviation).

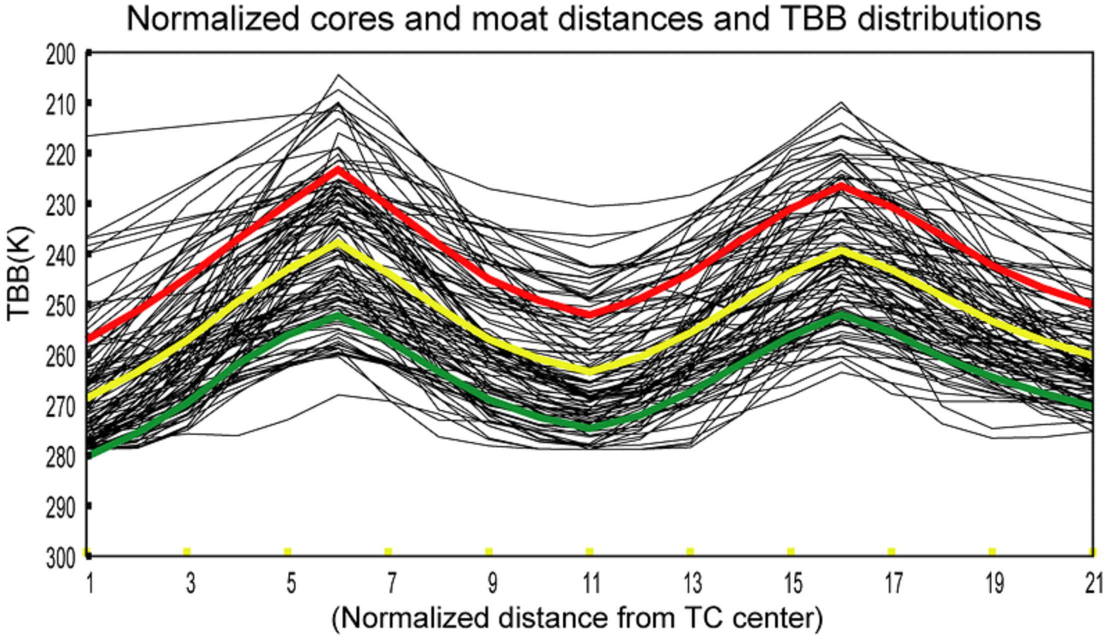

Fig. 3: Normalized cores and moats location and Tbb distributions.

IMPACT

Studying the relationship between the life cycle of the concentric eyewall structure and tropical cyclone intensity may shed lights on ways to improve intensity forecasting. The methodology being developed will enable more precise search for concentric eyewall structures from satellite data to produce a consistent data set for further analysis of the structure and dynamics.

RELATED PROJECTS

Taiwan's National Research Council project on tropical cyclone dynamics at National Taiwan University.

SUMMARY

A scheme is developed to objectively search for tropical cyclones with concentric eye structure from satellite microwave images. The method is applied to western North Pacific typhoons for 1997-2006 using SSMI 85GHz horizontal polarized orbital images obtained from NRL. The method can be applied to original satellite orbital data including satellites such as and NOAA-13, NOAA-14 and NOAA-15 polar orbital satellites. This method can be used for automatic recognition of double eyewall structure for all tropical cyclones if the time and location for each overpass of a typhoon can be precisely determined. Such determinations will require tremendous amount of time and manpower. Currently all the satellite data has been download to the local disk and all the typhoon cases have been identified and satellite antenna corrections have been performed on the Tbb data. The typhoon center locations and the time of the typhoon center overpass remain to be determined.

PUBLICATIONS

Lu, M. M. and C.-P. Chang: Unusual Late Season Cold Surges of the 2005 Asian Winter Monsoon. 21st Pacific Science Congress, Okinawa, Japan, Jun 2007.

Chang, C.-P., and T.S. Wong: Rare Typhoon Development Near the Equator. *Recent Advances in Atmospheric Sciences*, World Scientific, Singapore, in press.

Kuo, H. C., C.-P. Chang, and H.C. Jang: Concentric Eyewall Structure of Western North Pacific Typhoons: A Climatology. Third APEC Climate Center Symposium, Busan, Korea, September 2007.